(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
26 August 2010 (26.08.2010)

PCT

(10) International Publication Number
WO 2010/096355 A2

(51) International Patent Classification:
H05K 7/20 (2006.01) *F25B 39/02* (2006.01)
F25D 19/00 (2006.01)

(21) International Application Number:
PCT/US2010/024219

(22) International Filing Date:
15 February 2010 (15.02.2010)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/153,114 17 February 2009 (17.02.2009) US

(71) Applicant *(for all designated States except US)*: **PARKER HANNIFIN CORPORATION** [US/US]; 6035 Parkland Blvd., Cleveland, Ohio 44124-4141 (US).

(72) Inventors; and
(71) Applicants : **LOUVAR, Tim** [US/US]; 4228 Holly Tree Place, Fort Wayne, Indiana 46804 (US). **GILL, Scott** [US/US]; 2903 McComb Road, New Haven, Indiana 46748 (US). **THOMPSON, Dale** [US/US]; 1817 Glenlivet Court, Fort Wayne, Indiana 46804 (US).

(74) Agents: **CLARK, Robert** et al.; 6035 Parkland Blvd., Cleveland, Ohio 44124-4141 (US).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *without international search report and to be republished upon receipt of that report (Rule 48.2(g))*

WO 2010/096355 A2

(54) **Title**: COOLING SYSTEM UTILIZING MULTIPLE COLD PLATES

(57) **Abstract**: A cold plate subassembly is provided for a liquid refrigerant cooling system wherein the cold plate subassembly includes multple cold plate/evaporatos in thermal contact with teh electrical or electronic component to be cooled and the multiple cold plate/evaporators are in thermal conductive contact with each other.

Cooling System Utilizing Multiple Cold Plates

CROSS-REFERENCE TO RELATED CASES

[0001] This application claims the benefit of U.S. Provisional Application Ser. No. 61/153,114; filed February 17, 2009, the disclosure of which is expressly incorporated herein by reference.

TECHNICAL FIELD

[0002] The present invention relates to cooling of electrical and electronic components, and more particularly, to a cold plate subassembly used in a liquid refrigerant cooling system wherein the cold plate subassembly comprises multiple cold plate/evaporators in thermal contact with the electrical or electronic component to be cooled and in thermal conductive contact with each other.

BACKGROUND

[0003] Electrical and electronic components (e.g. microprocessors, IGBT's, power semiconductors, etc.) are most often cooled by air-cooled heat sinks with extended surfaces, directly attached to the surface to be cooled. A fan or blower moves air across the heat sink fins, removing the heat generated by the component. With increasing power densities, miniaturization of components, and shrinking of packaging, it is sometimes not possible to adequately cool electrical and electronic components with heat sinks and forced air flows. When this occurs, other methods must be employed to remove heat from the components.

[0004] One method for removing heat from components when direct air-cooling is not possible uses a single-phase fluid which is pumped to a cold plate. The cold plate typically has a serpentine tube attached to a flat metal plate. The component to be cooled is thermally attached to the flat plate and a pumped single-phase fluid flowing through the tube removes the heat generated by the component.

[0005] There are many types of cold plate designs, some of which involve machined grooves instead of tubing to carry the fluid. However all cold plate designs operate similarly by using the sensible heating of the fluid to remove heat. The heated fluid then flows to a remotely located air-cooled coil where ambient air cools the fluid before it returns to the pump and begins the cycle again. This method of using the sensible heating of a fluid to remove heat from electrical and electronic components is limited by the thermal capacity of the single phase flowing fluid. For a given fluid to remove more heat, either its temperature must increase or more fluid must be pumped. This creates high temperatures and/or large flow rates to cool high power microelectronic devices. High temperatures may damage the electrical or electronic devices, while large flow rates require pumps with large motors which consume parasitic electrical power and limit the application of the cooling system. Large flow rates may also cause erosion of the metal in the cold plate due to high fluid velocities.

[0006] Yet another method which is employed when direct air-cooling is not practical uses the well-known vapor compression refrigeration cycle. In this case, the cold plate is the evaporator of the cycle. A compressor raises the temperature and pressure of the vapor, leaving the evaporator to a level such that an air-cooled condenser can be used to condense the vapor to its liquid state and be fed back to the cold plate for further evaporation and cooling. This method has the advantage of high isothermal heat transfer rates and the ability to move heat considerable distances. However, this method suffers from some major disadvantages which limit its practical application in cooling electrical and electronic devices. First, there is the power consumption of the compressor. In high thermal load applications the electric power required by the compressor can be significant and exceed the available power for the application. Another problem concerns operation of the evaporator (cold plate) below ambient temperature. In this case, poorly insulated surfaces may be below the dew point of the ambient air, causing condensation of liquid water and creating the opportunity for short circuits and hazards to people. Vapor compression refrigeration cycles are designed so as not to return any liquid refrigerant to the compressor which may cause physical damage to the compressor and shorten its life by diluting its lubricating oil. In cooling electrical and electronic components, the thermal load can be highly variable, causing unevaporated refrigerant to exit the cold plate and enter the compressor. This can cause damage and shorten the life of the compressor. This is yet another disadvantage of vapor compression cooling of components.

SUMMARY

[0007] At least one embodiment of the invention provides a cooling system comprising: a single component generating heat and required to be cooled; at least two cold plate evaporator devices, each in thermal contact with the component and in direct conductive contact with each other; a liquid refrigerant pump; a vaporizable refrigerant circulated by the liquid refrigerant pump to the at least two cold plate evaporator devices, whereby the refrigerant is at least partially evaporated by the heat generated by the component, creating a vapor; a condenser for condensing the partially evaporated refrigerant vapor, creating a single liquid phase; and a conduit for the vaporizable refrigerant to move between the at least two cold plate evaporator devices, condenser, and liquid refrigerant pump.

[0008] At least one embodiment of the invention provides a cold plate subassembly for cooling an electronic component, the subassembly comprising: at least two cold plate evaporator devices, each cold plate in direct conductive contact with an adjacent cold plate effectively forming a single heat transfer plate contacting the single component generating heat; wherein the at least two

cold plate evaporator devices are mounted to a single base plate; wherein the at least two cold plate devices are fluidly connected in series.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] Embodiments of this invention will now be described in further detail with reference to the accompanying drawings, in which:

[0010] FIG. 1 is a schematic diagram of a prior art vaporizable dielectric cooling system;

[0011] FIG. 2 is a schematic diagram of an embodiment of the vaporizable dielectric cooling system of the present invention; and

[0012] FIG. 3 is a schematic diagram of an embodiment of the vaporizable dielectric cooling system of the present invention.

DETAILED DESCRIPTION

[0013] An embodiment of the vaporizable dielectric cooling system of the present invention is shown in FIG. 1. The system 10 comprises a pump 12, an evaporator in the form of a cold plate subassembly 18, and a condenser 28, the components connected to each other by various fluid conduits 26.

[0014] The cooling system 10 operates isothermally, since it uses change of phase to remove heat rather than the sensible heat capacity of a liquid coolant. This allows for cooler temperatures at the evaporator and cooler components than a single-phase liquid system. Low liquid flow rates are achieved through the evaporation of the working fluid to remove heat, keeping the fluid velocities low and the pumping power very low for the heat removed.

[0015] Referring again to FIG. 1, cooling system 110 circulates any suitable vaporizable refrigerant, such as R-134a. The cooling cycle can begin at liquid pump 12, shown as a Hermetic Liquid Pump. Pump 12 pumps the liquid phase refrigerant to a cold plate subassembly 18, comprising a plurality of cold plates 37A, 37B, 37C, as best shown in FIG. 2. Each cold plate 37A, 37B, 37C, is in thermal contact with an electrical or electronic component or components to be cooled, causing the liquid refrigerant to evaporate at system pressure. None, some, or all of the liquid refrigerant may evaporate at cold plates 37A, 37B, 37C, depending on how much heat is being generated by the particular component. In most cases, some of the refrigerant will have evaporated and a two-phase mixture of liquid and vapor refrigerant will leave each cold plate 37A, 37B, 37C in series. The vapor moves to the condenser 28 through line 26, wherein the condenser 28 removes the heat generated by the electronic components. The liquid refrigerant exits the condenser 28, and is sent to the pump 12 and the cooling cycle begins again.

[0016] Referring now to FIGS. 2 and 3, an embodiment of the cold plate subassembly 18 of the present invention is shown which comprises an inlet tube 31 to a first cold plate 37A which comprises a cold plate cavity housing 34, a cold plate fin pack 36 positioned in the cavity of the housing 34 and a cold plate lid 38 enclosing and sealing the cavity of the housing 34. A transfer tube 32 forms an outlet from the first cold plate 37A and serves as an inlet to the adjacent second cold plate 37B. A third cold plate 37C adjacent the second cold plate 37B receives refrigerant from a second transfer tube 32. Refrigerant exits the cold plate subassembly 18 through outlet 39. The number of cold plates may be two or more cold plates positioned adjacent to each other and in direct conductive contact with an adjacent cold plate. While the cold plates 37A, 37B, 37C of the subassembly 18 are shown in series, it is contemplated that cold plate subassembly 18 can be configured with a plurality of cold plates in parallel.

[0017] The cold plates 37A, 37B, 37C may be attached to a base plate 35 using suitable fasteners and mounting holes 33. The cold plates 37A, 37B, 37C are in direct contact with their respective adjacent cold plates while positioned in base plate 35. The direct contact allows conduction between cold plates to better spread the heat generated by the heat generating component and thus provides better cooling as compared to cold plates that are separated from each other. The cold plate subassembly 18 allows multiple passes of the refrigerant to cool a component instead of a single pass as in the prior art cold plates.

[0018] The cold plates of the present invention provide several advantages over the prior art. The cold plates are easier and less costly to manufacture a single large cold plate. Using the phase change process, each cold plate is the same temperature as the previous, such that the system is isothermal. There is better thermal contact with the base plate of the IGBT. It is also easier to maintain flatness across the smaller surface of the cold plate as the smaller cold plates are less prone to warpage.

[0019] Although the principles, embodiments and operation of the present invention have been described in detail herein, this is not to be construed as being limited to the particular illustrative forms disclosed. They will thus become apparent to those skilled in the art that various modifications of the embodiments herein can be made without departing from the spirit or scope of the invention.

CLAIMS

1. A cooling system comprising:

a single component generating heat and required to be cooled;

at least two cold plate evaporator devices, each in thermal contact with the component and in direct conductive contact with each other;

a liquid refrigerant pump;

a vaporizable refrigerant circulated by the liquid refrigerant pump to the at least two cold plate evaporator devices, whereby the refrigerant is at least partially evaporated by the heat generated by the component, creating a vapor;

a condenser for condensing the partially evaporated refrigerant vapor, creating a single liquid phase; and

a conduit for the vaporizable refrigerant to move between the at least two cold plate evaporator devices, condenser, and liquid refrigerant pump.

2. The cooling system of claim 1, wherein the at least two cold plate devices are fluidly connected in series.

3. The cooling system of claim 1, wherein the at least two cold plate devices are both housed on a single base plate.

4. The cooling system of claim 1 comprising at least three cold plates wherein each of the cold plates.

5. The cooling system of claim 4, wherein the at least three cold plate devices are fluidly connected in series.

6. The cooling system of claim 4, wherein the at least three cold plate devices are both housed on a single base plate.

7. The cooling system of claim 1, wherein each of the cold plates comprises a cold plate cavity housing, a cold plate fin pack positioned in the cavity of the housing, and a cold plate lid enclosing and sealing the cavity of the housing.

8. The cooling system of claim 7, wherein the cold plate lids of the at least two cold plate devices are formed as generally rectangular plates and are positioned adjacent to each other effectively forming a single heat transfer plate contacting the single component generating heat.

9. A cold plate subassembly for cooling an electronic component, the subassembly comprising:

at least two cold plate evaporator devices, each cold plate in direct conductive contact with an adjacent cold plate effectively forming a single heat transfer plate contacting the single component generating heat;

wherein the at least two cold plate evaporator devices are mounted to a single base plate;

wherein the at least two cold plate devices are fluidly connected in series.

10. The cooling system of claim 9, wherein each of the cold plate devices comprises a cold plate cavity housing, a cold plate fin pack positioned in the cavity of the housing, and a cold plate lid enclosing and sealing the cavity of the housing.

11. The cooling system of claim 10, wherein the cold plate lids of the at least two cold plate devices are formed as generally rectangular plates and are positioned adjacent to each other effectively forming a single heat transfer plate contacting the single component generating heat.

12. The cooling system of claim 9 comprising at least three cold plate devices.

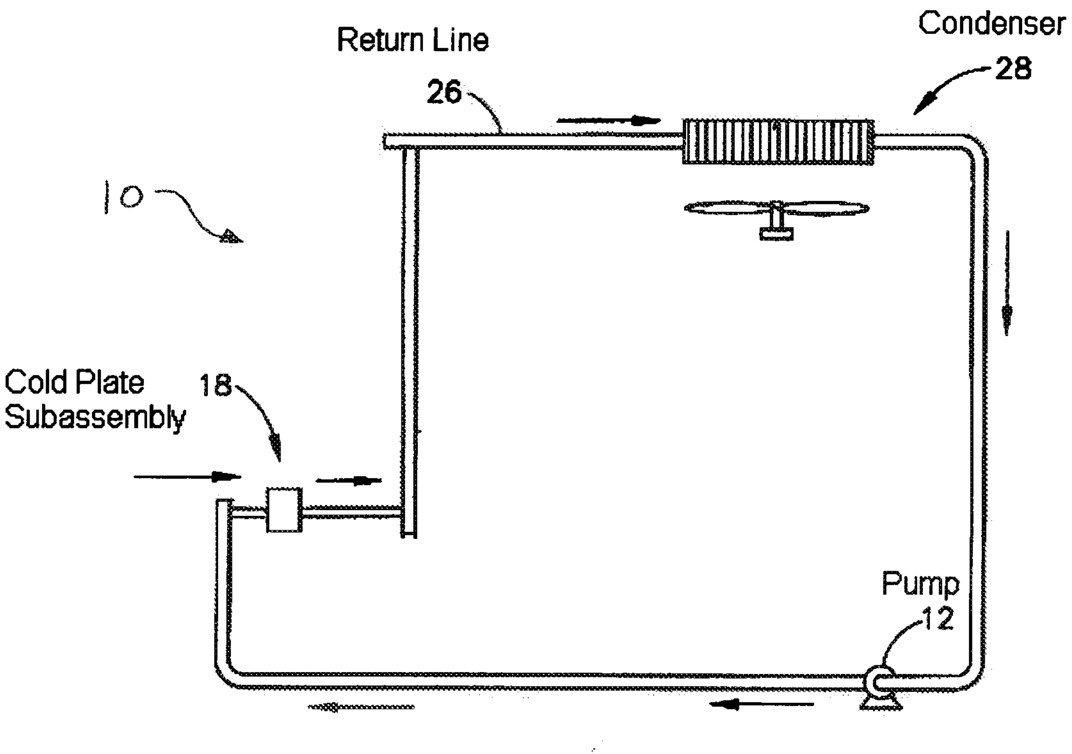
Return Line
Condenser
28
26
10
Cold Plate Subassembly
18
Pump
12

FIG. 1

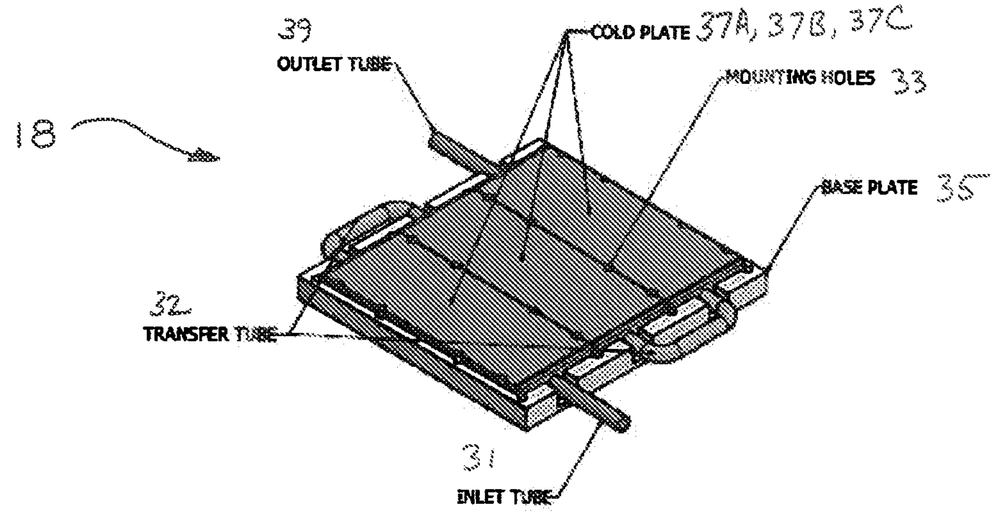
39
OUTLET TUBE
COLD PLATE 37A, 37B, 37C
MOUNTING HOLES 33
18
BASE PLATE 35
32
TRANSFER TUBE
31
INLET TUBE

FIG. 2

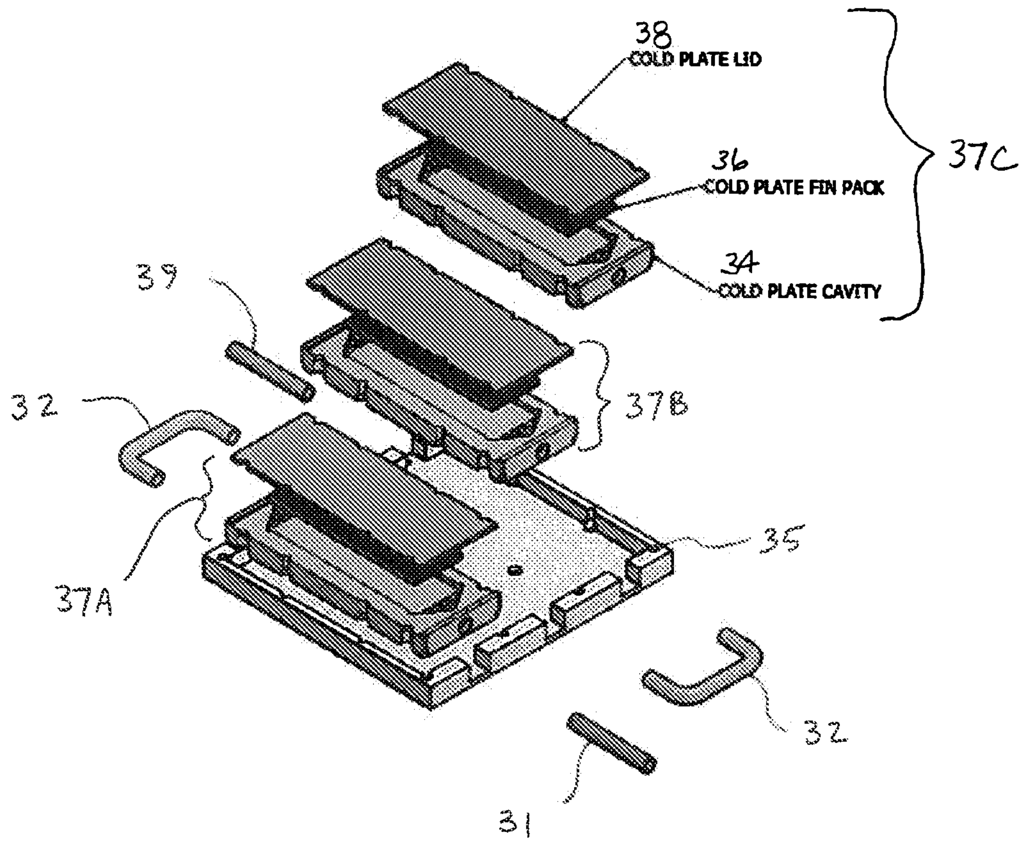
38
COLD PLATE LID
36
COLD PLATE FIN PACK
34
COLD PLATE CAVITY
37C
39
32
37B
35
37A
32
31

FIG. 3